THE STUDY ON PRODUCTION OF BIO-OIL FROM SAWDUST AND OIL PALM FRONDS BIOMASS USING GAS FIRED PYROLYSIS SYSTEM

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ABSTRACT

Fast pyrolysis of biomass is the most promising technology of exchanging solid biomass to liquid bio-oil as a renewable substitution of fossil resources in fuel and chemical feedstock'spurposes. Malaysia with abundant biomass resources allows an ideal platform for the growth of this thermal conversion technology. Biomass fast pyrolysis is rapidly developing interest in Malaysia as it is considered to offer efficient logistical and hence economic advantages over other thermal conversion process. In this study, pyrolysis of sawdust and oil palm fronds were investigated under various heat distribution and pyrolysis temperature in gas fired reactor. The heat distribution was done in different setting of fuel and air of gas burner. The setting are 16mbar of fuel with 7.5 air, 19mbar of fuel with 2.5 air and 19mbar of fuel with 5.0 air. The best setting of fuel and air ratio is the setting 19mbar of fuel with 2.5 air ratio where it give shortest time to reach 400^{o}C of the temperature of the reactor. The temperatures of pyrolysis were varied in range of 400^{o}C-600^{o}C. The products obtained from pyrolysis of waste furniture sawdust and palm oil stem were bio-oil, char and gas. The maximum bio-oil yield was obtained at temperature 500^{o}C. This study provides better insight on heat distribution and temperature of the reactor.

ABSTRAK

Proses pirolisis biojisim merupakan teknologi yang menjanjikan pertukaran biojisim daripada pepejal kepada cecair yang boleh diperbaharui sebagai bahan ganti sumber fosil dalam bahan api dan sebagai bahan mentah kimia. Malaysia sebagai sebuah negara yang mempunyai banyak sumber biojisim menyediakan platform ideal untuk pertumbuhan teknologi penukaran terma ini. Proses pirolisis biojisim di Malaysia semakin pesat membangun dimana ia dianggap menawarkan kelebihan logistik yang cekap dan dengan itu memberi kelebihan ekonomi atas proses pengubahan terma lain. Dalam kajian ini, pirolisis habuk kayu dan pelepah pokok kelapa sawit telah disiasat di bawah berbagai-bagai pengedaran haba dan suhu dalam reaktor pirolisis. Pengedaran haba telah dilakukan pada persekitaran bahan api dan udara penunu gas yang berbeza. Persekitaran ditetapkan pada 16mbar bahan api dengan 7.5 udara, 19mbar bahan api dengan 2.5 udara dan 19mbar bahan api dengan 7.5 udara. Persekitaran terbaik bahan api dan pengudaraan adalah pada persekitaran 19mbar bahan api dengan 2.5 udara dimana ia memberi masa terpantas untuk mencapai suhu reaktor pada 400^{o}C. Suhu-suhu pirolisis diubah dalam julat 400^{o}C hingga 600^{o}C. Produk-produk yang diperolehi daripada proses pirolisis habuk kayu dan pelepah pokok kelapa sawit merupakan minyak, arang dan gas. Hasil minyak maksimum telah diperolehi pada suhu 500^{o}C. Kajian ini menyediakan wawasan yang lebih baik keatas pengedaran haba dan suhu reaktor.

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INTRODUCTION

1.1 Research Background

The challenge to overcome the decimation of fossil fuels especially the petroleum based fuels is the critical issue of this century. Petroleum fuels have been considered as a key component in the crucial energy and natural resources sector which drives the economic progress. Almost the human activities depend heavily on this physical resource. Aside from transportation and power generation, mass quantities of petroleum and petroleum derived chemicals are necessary for manufacturing, food processing, medicine and all other industries as raw materials and fuels. Nature may have been kind to human but the size of these physical mineral resources is limited. All the reservoirs that exist in this planet will be recovered sooner or later (Lim Xin Yi, 2008 and Mabro, 2003). Although International Energy Agency (IEA, 2004) reported that the Earth's petroleum resources are more than sufficient to meet demand until 2030 and well beyond, they also pointed out that there would be uncertainties about how much it will cost to extract them and deliver them to consumers. In other word, oil reserves are not running out but it will become more difficult and expensive to recover it without any significant breakthrough in extraction tecnology or discovery of new oil feilds.

In the decimation of petroleum and the increasing of demand for alternative resources, biomass is receiving higher attention as it is one of the most available renewable energy resources that can be use to decrease the dependency on fossil resources (Lim Xin Yi, 2008 and Williams et. al., 2000). Agricultural waste is one form of the biomass which is generated consistently in large amount from the agriculture activities. Some of these agricultural wastes are be used as fuel for energy recovery scheme to generate the heat and electricity required for the milling processes. However, theuseage of biomass for energy conversion through combustion is still regarded limited due to its poor fuel properties such as high moisture, ash contents, low bulk density and low energy content. These properties leading to difficulties in storage, handling and transport which restrictions the biomass application as commodity fuels. Exceed biomass yielded not only created waste disposal problems but also regarded as waste of primary resources.

Biomass iswidely considered as a sustainable source of renewable energy particularly in countries where is plentiful agricultural activities.The use of these materials will depend on a safe state of the art, economics and technologies that are used to transform them into manageable products (Sensoz et.al,2006). Over the last two decades,special attention to the conversion of residual biomass and renewable materials into bio-oil. Bio-oil is renewable and biodegradable. Moreover, it does not contribute to a net rise in the level of CO_2 in the atmosphere and consequently to the greenhouse effect. Energy production can be produced from biomass in several ways from old direct burning to modern gasification and fast pyrolysis. For the recovery of maximum energy from a particular biomass, the technically and economically viable process should be selected (H.L.Chum and R.P. Overend,2001). By direct combustion, the biomass will completely transformed into heat which only 10-15% is effectively heated the target. Thus the commercial energy production by this process is not economically viable at present. The fast pyrolysis and gasification are the modern techniques for the conversion of biomass into combustible liquid (pyrolysis oil) and gaseous fuels.

Pyrolysis is one of the most promising technologies for biomass utilization (Bridgwater et.al,1999; Kawaser et.al,2004) , which converts biomass to bio-oil, char and gases depending on the pyrolysis conditions. Pyrolysis can be described as a thermal degradation of materials in the complete absence or inadequate presence of oxygen. Pyrolysis oil can be used for the production of renewable or sustainable energy and chemicals (D.R. Huffman et.al,1995).An ages ago, it was used to produce charcoal from wood for heating and smelting metals from various ores. Charcoal for barbecues has been produced on a small scale in Malaysia at present time. Modern pyrolysis technology is developing for the maximum liquid production instead of merely charcoal and coke. Pyrolysis processes offers several options for upgrading biomass to increase the overall applicability of biomass for large scale production. The amount and nature of the end products of pyrolysis will depend on the operating temperature, the heating rate, the residence time and the compositions of the biomass.

Malaysia is blessed with abundant natural resources and bears a favorable climate for commercial cultivation of crops such as oil palm.Agriculture and forest products industries produce food, feed, fiber and a wide range of require products like shelter, packaging, clothing and communications. Yet, biomass is also a source of a many variety of chemicals and materials and of electricity and fuels (Chum and Overend, 2001). In Malaysia, the organic or naturalwastes were available almost free-of-charge andcontributes towards the environmentally cleandisposal of organic or natural waste.

In the wood based industry, the removal of wood waste isan important activity where it can gives a certain extentaffects the productivity and profitability of the milloperation. In a typical Malaysian sawmill, the waste are loaded in a specially constructed bin or rack andremoved by forklift to the waste collection site orincinerator. In sawmilling, the sawdust generated is approximately 8% of the total volume of log input. Generally it is assume that the volume of sawdust is about three timesthe volume of wood which it is made up of. The rate of sawdust being generated is about $18m^3$/day.

In Malaysia the overall plantation area of oil palm was 4,487,957 ha in 2008. It has been reported that in 2005 there was 423 palm oil mills having production capacity of approximately 89 million tonnes of fresh fruit bunches per year (R.P.Singh et.all, 2010) .Oil palm solid wastes are low-priced and abandonedmaterials formed in palm oil milling process.About 80%of solid wastes are used as boiler fuel in industrywhile the remaining 20% are abandoned (Pensamut et.al,2003). It isalso estimated that approximately 1.18 x 106 tons oforganic waste was produced from the palm oil mills.

1.2 Prolem Statement

World today is facoused on renewable energy to replace fossil fuel sources. Pyrolysis process is one of the method that being used to produced renewable energy.

The conversion of heat to the pyrolysis system is an important aspect for the heat distribution. Based on the previous study, using electricity for heating is not efficient because the energy conversion of heat by electricity will only have 40% of efficiency.

Temperature of the pyrolysis process can give effect to the yields of pyrolysis products. At different temperature, the yield of liquid, gas and char will be varies.

1.3 Statement of Objectives

The objectives of the research is to find the best setting of fuel and air ratio that can achieve the pyrolysis process temperature in the shortest time.Other objectives is to study the maximum yield of bio-oil pruduct from the pyrolysis of sawdust and oil palm fronds.

1.4 Scope of the Study

This research mainly focuses on

1. Run the experiment on the system with different setting of fuel and air of gas burner.
2. Find the best fuel and air setting that can achieve the pyrolysis process temperature in the shortest time.
3. Run the experiment on two difference raw material that is sawdust and oil palm fronds at difference temperature.
4. Find the maximum yield of bio-oil and the best temperature.

1.5 Rationale and Significance

During the research, knowledge about the production of bio-oil from the pyrolysis process can be gained. Besides, the heat distribution of the gas fired pyrolysis system can be learn. The technical elements on controlling and handling the equipment such as gas burner also can be gain in this research.

Therefore, experiment to get the optimum setting of fuel and air setting of gas bernur also being run. The experiment cover on the gas burner with controlling the setting of the fuel and air setting and make sure that the temperature in the furnace nad reactor achieve the pyrolysis process temperature in the shortest time.Other than that, there are several experiments have been run such as eperiment to get the maximum bio-oil yeild for sawdust and oil palm fronds. The experiment cover on the maximum production of bio-oil and the best temperature to obtain maximum bio-oil yeild.

Hence, in the end of the experiments, the best setting of fuel and air of gas burner can be selected. Also,the maximum bio-oil yeild can be calculate and the best temperature can obtain. So, after all the aspects covered, it will accomplish this research well.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Concern over the global warming and finite fossil fuel reserves have led to the realisation that a more enviromentally friendly, flexible transport infrastructure is required. While solutions with efficiencies that surpass the current combustion engine are likely to be developed, this will take time, and furthermore current consumer preferences favour liquid alkane fuels (Alonso DM *et al*,2010).Biofuels are seen as the possible solution for this problems. Global production of biofuels has increased rapidly to 83 billion litres in 2008, but still retains a small share of the transport fuel market (IEA,2009).The first generation biofuels have encountered significant criticisms over their ability to achieve meaningful substitution, climate change mitigation and economic growth. While more advanced second generation technologies do not completely overcome these problems, they are none-the-less expected to become at least a part of the solution in the shift from fossil resources in the short to medium term (IEA,2010 & Sims REH *et al*,2008). It is expected that second generation biofuels will be produced under commercially viable conditions between 2015 and 2020 (Sims REH *et al*,2008). Such technologies can be classified as biochemical or thermochemical.It is has been suggested that biochemical and thermochemical technologies could be employed synergistically in integrated biorefineries with the added benefit of increased flexibility and efficiency (Jae J *et al*,2010).Thermochemical processes depend on the relationship between heat and chemical action as a means of extracting and creating products and energy. Main biomass thermochemical conversion processes are pyrolysis, gasification, and liquefaction.Figure 2.1 shows the main biomass thermochemical conversion processes.

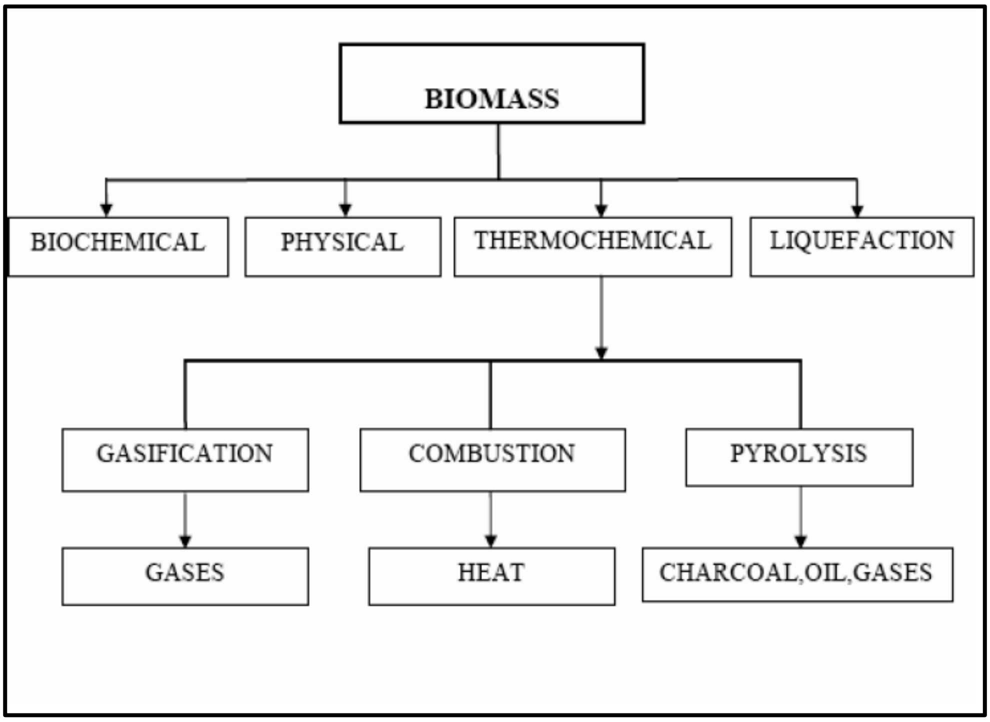

Figure 2.1 : The Main Type and Process of Biomass

(Ani 2006)

2.2 Biomass

Biomass consist of all the living matter present on the earth. It is derived from growing plants including algae, trees and crops or from animal manure (Bridgewater,1999). The biomass resources are the organic matters in which the solar energy is stored in chemical bonds. It generally consists of carbon, hydrogen, oxygen and nitrogen. Sulfur also present in minor proportions and some biomass also consist significant amounts of inorganic species. Plants, via photosynthesis, produce carbohydrates which form the building blocks of biomass (Demirbas,2001). Through photosynthesis process, biomass absord and stored the energy from the sun. The chemical energy in plants gets passed on to animals and people when they eat the plants. Biomass is a renewable energy source because trees and crops will always grow day by day and the waste will always exist. Wood, crops, manure and some garbage are some examples of biomass.

Biomass is part of the carbon cycle, where carbon in the air is converted into a biological matter using photosynthesis. Biomass is seen as more environmentally friendly and longer lasting than traditional fossil fuels. Another significant advantage of biomass over fossil fuels is that the biomass sourcescan be grown almost anywhere in the world and suitable for producing biomass and bio-fuel. Fossil fuels like petrol or gas and other traditional fuel types are only produced in certain areas of the world and takes long time to produced.

In Malaysia, biomass is one of the most important potential sources of renewable energy. Biomass resources are available from palm oil plantations, forestry and wood industry, rice husk and several other agricultural sources and agro-industries. Presently the largest fraction of solid biomass fuels is used as a boiler fuel in palm oil industry, but also to some extent in wood industries, rice mills and sugar mills (Anders Evald et al., 2005). The present utilization of solid biomass fuels takes place in industries, that have direct access to the biomass and who are used to handling large volumes of the products.

2.3 Type of Biomass

Biomass can be split into two distinct categories:

a. Waste Biomass
b. Energy Crops

Each will give different range of product either liquid, gas and char. Physical conversion involved densification more easily handled such as briquettes particles, palletized fuel and fuel logs. These involve extrusion process of biomass particles with or without binder at higher pressure and later carbonized to obtain charcoal material (Ani, 2006).

2.3.1 Waste Biomass

2.3.1.1 Forestry Residue

Forestry residues include biomass that is not harvested or removed from logging sites in commercial forests as well as material resulting from forest management operations such as pre-commercial thinnings and removal of dead and dying trees.Wood is the most commonly used biomass fuel for heat and power generation. Using these materials for electricity generation recovers their energy value while avoiding landfill disposal.Forestry waste includes logging residues, imperfect commercial trees, dead wood and other non-commercial trees that need to be thinned from crowded, unhealthy and fire-prone forests.

2.3.1.2 Animal Farming

Farm slurries is on of the example for animal farming. Farm slurry is a watery animal sewage containing a high concentration of suspended solids. Farm slurries are obtained mainly from pig farming and cattle farming. Several options for collecting and storing swine manure are available, depending on the manure form. Common storage methods include underfloor pits, outdoor structures, earthen pits, lagoons and holding ponds.The techniques for cattle farming is significantly affect the quantity and quality of manure that may be delivered to the anaerobic digestion system. The number of cows, the housing, transport, and bedding systems used by the farms determines the amount of slurry that must be used and therefore the amount of energy produced.The type of housing used determines the quantity and quality of manure that can be econom ically collected.

2.3.1.3 Organic Municipal Solid Waste (MSW)

Organic MSW is any matter collected from commercial or residential properties such as food waste, paper and others.

2.3.1.4 Slaughterhouse and Fishery Waste

At a slaughterhouse or a fish processing plant, there is a huge amount of organic waste. This has the possibility of being a danger to the environment and human or animal health.

2.3.1.5 Sewage Waste

Sewage waste is a source of biomass that is comparable to the other animal wastes previously mentioned. Energy can be extracted from sewage using anaerobic digestion, pyrolysis or drying and incineration.

2.3.2 Energy Crops

2.3.2.1 Short Rotation Coppice (SRC)

SRC is a densely planted, high-yielding varieties of either willow or poplar, harvested on a 2 to 5 year cycle, although commonly every 3 years. SRC is a woody, perennial crop, the rootstock or stools remaining in the ground after harvest with new shoots emerging the following spring. A plantation could last up to 30 years before re-planting becomes necessary.

2.3.2.2 Pellets

Pellets are a refined, solid fuel biomass with a low moisture content, which makes it easy to transport, store and convert into energy. It is manufactured from saw dust, wood chips, shaving or bark. Pellets are typically 6-8mm in diameter and 5-30 mm long. The maximum water content is 8%.The following list contains the main advantages of using pellets:

a. Pellets burns almost without any smoke development. The dust in the flue gas is very basic.
b. The ash produced is basic.
c. Less carcinogens are produced in the high temperature combustion of pellets compared with unrefined fuel.
d. It has a low heavy metal content.
e. Only small quantities of NOX oxides are formed.

2.3.2.3 Woodchips

The term woodchips refers to mechanically processed wood particles, ranging in size from 1 to 100 mm. The criteria used for woodchip quality are as follows:

a. Chip size: only the "fine" (smaller than 30 mm) and "medium" grades (below 50 mm) are suitable for small-scale installations;
b. Water content: this determines the energy content of the fuel on the one hand and its storability on the other;
c. Bulk density: this indicates the weight per cubic metre (bulk volume) and depends on wood type, particle shape, degree of compaction and water content.

2.4 Biomass Utilization

Biomass has always been a major source of energy for mankind from ancient times. Presently, it contributes around 10–14% of the world's energy supply (Putun AE,et al., 2001). Biomass can be converted into three main types of products:

a. Electrical or heat energy.
b. Fuel for transport sector.
c. Feedstock for chemicals.

Traditionally, biomass had been utilized through direct combustion. Burning biomass produces pollutants including dust and the acid rain gases such as sulfur dioxide and nitrogen oxides but the sulfur dioxide produced is 90% less than that is produced by burning coal. The quantities of atmospheric pollution produced are insignificant compared to other pollution sources. Biomass usage as a source of energy is of interest due to the following envisaged benefits:

1.Biomass is a renewable, potentially sustainable and relatively environmentally friendly source of energy.
2. A huge array of diverse materials, frequently stereo chemically defined, are available from the biomass giving the user many new structural features to exploit [Bozell Joseph J, 1999].

3. Increased use of biomass would extend the lifetime of diminishing crude oil supplies.
4. Biomass fuels have negligible sulfur content and, therefore, do not contribute to sulfur dioxide emissions that cause acid rain.
5. The combustion of biomass produces less ash than coal combustion and the ash produced can be used as a soil additive on farms, etc.
6. The combustion of agricultural and forestry residues and municipal solid wastes (MSW) for energy production is an effective use of waste products that reduces the significant problem of waste disposal, particularly in municipal areas.
7. Biomass is a domestic resource which is not subject to world price fluctuations or the supply uncertainties as of imported fuels.
8. Biomass provides a clean, renewable energy source that could improve our environment, economy and energy securities [Othmer K, 1980].
9. Biomass usage could be a way to prevent more carbon dioxide production in the atmosphere as it does not increase the atmospheric carbon dioxide level.

Biomass can be used in many ways to obtain energy. Most of the biomass energy is consumed in domestic purposes and by wood-related industries. It is burned by direct combustion to produce steam that drives the turbine or generator to produce electricity. Gasifiers are used to convert biomass into a combustible gas which is then used to drive a high efficiency, combined cycle gas turbine. Biomass is converted to pyrolysis oil byheating. Pyrolysis oil is easier to store and transport than solid biomass material and is burned like petroleum to generate electricity.

2.5 Biomass in Malaysia

Today, about 80% of Malaysia's total population lives in Peninsular Malaysia, the hub of the country's economic activities. Like many other developing countries, energy has been the prime contributor towards the rapid growth of Malaysia's economy. Malaysia is looking forward in industrial and development sector that need sustainable energy resources.

The available fossil fuels sources now only can survive for another 20 to 30 years (Hisyam, 2006). Malaysia is the largest producer and exporter of palm oil in the world, accounting for 30% of the world's traded edible oils and fats supply. 3.88 million hectares of land in Malaysia is under oil palm cultivation producing 14 million tonnes of palm oil in 2004 (Jessada, 2007).

Malaysia government need fully supports re-biomass based power generation through various initiative and promotion program such as biogen since biomass resources is big potential for Biomass Power Co-Generation and beside that Malaysia can develop and expend the market profitability through new technology and lower production cost to overcome the challenges (Hamdan, 2004).

Energy has contributed significantly towards the rapid growth of the Malaysia economy. Energy supply infrastructure needs to be more continuously developed and being very capital intensive, it will impose tremendous pressure on the depleting resources. Successful implementation of this biomass utilization would provide the oil palm industry with an additional substantial income of over RM30 billion per year in addition to the current RM15 billion per year from the oil and its derivatives speech from Minister of Primary Industries, Dato' Seri Dr. Lim Keng Yaik in the launched the Biomass Technology Centre (BTC) and the Farm Mechanization Centre (FMC) of the Malaysian Palm Oil Board (MPOB) in Bangi, Selangor, on 5 February 2002.

Furthermore, compare to the cost of fossil fuels that increasing by year in Malaysia, there is a strong reason to produce gases using cheaper raw material. As biomass is created by plants absorbing $CO_2$from the air, releasing this CO_2 when oxidizing biomass does not lead to a net increase in greenhouse gas (GHG) emissions if biomass is produced in a sustainable manner. Carbon dioxide has been targeted as the greenhouse gas.